

REMARKS

Claims 74-80, 82 and 83 are currently pending in this application. Applicant reserves the right to pursue the original and other claims in this and other applications. Applicant respectfully requests reconsideration in light of the following remarks.

Claims 74 and 75 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Okada (U.S. Patent No. 6,424,036) ("Okada") in view of Tsai et al. (U.S. Patent No. 6,479,398) ("Tsai"). This rejection is respectfully traversed and reconsideration is respectfully requested.

Claim 74 recites a copper bond pad for a semiconductor device including a "dielectric layer," a "barrier layer," a "copper layer having titanium implanted within and near only an upper surface of [the] copper layer, [the] copper layer being primarily copper and having a thickness of about 500 Angstroms to about 20,000 Angstroms," and an "insulating layer over [the] copper layer." The "implanted titanium acts to reduce formation of copper oxide on [the] copper layer."

Thus, the claimed invention relates to a multi-layered copper bond pad on which the formation of copper oxide is inhibited. This is accomplished by implanting titanium into the copper layer, which suppresses the copper oxide growth by controlling the concentration of vacancies available to the copper ion transport.

Okada relates to a method of forming, with a reduced number of steps, semiconductor devices including barrier metal films between an insulating film and the copper layer and between copper layers. Okada Abstract; FIG. 5. As stated in the Office Action, Okada does not disclose a copper layer having titanium implanted within and near only an upper surface of the copper layer. Office Action, pg. 2. The Office Action relies on Tsai for this feature. Tsai relates to a method of forming special

copper alloy films which may be used to fill high aspect ratio vias and trenches. Tsai Abstract. The method deposits a layer of pure copper and then a copper alloy film over the copper either by PVD or sputtering. Id. Another embodiment then utilizes an annealing step. Id.

Applicant respectfully submits that the combination of Okada and Tsai does not disclose, teach or suggest all of the limitations of claim 74. Specifically, the cited combination does not disclose, teach or suggest a “copper layer having titanium implanted within and near only an upper surface of said copper layer, said copper layer being primarily copper and having a thickness of about 500 Angstroms to about 20,000 Angstroms . . . wherein said implanted titanium acts to reduce formation of copper oxide on said copper layer.”

Assuming Okada and Tsai are combinable, which Applicant does not concede, the resulting structure would include either a copper alloy layer formed merely on a top surface of the copper layer (FIG. 2B) or copper alloy formed throughout the copper layer (FIG. 2C; Col. 5, lines 59-64). The claimed invention, on the other hand, requires the “implanted titanium” to be “within and near only an upper surface of said copper layer.” (emphasis added). Additionally, the implanted titanium of the claimed invention “acts to reduce formation of copper oxide on said copper layer.” These claim limitations are not disclosed in or suggested by the combination of Okada and Tsai.

Accordingly, claim 74 is allowable over the cited combination. Claim 75 depends from claim 74 and is allowable along with claim 74. Applicant respectfully requests that the rejection of claims 74 and 75 be withdrawn and the claims allowed.

Claims 76-78 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Okada in view of Tsai and further in view of Hsu et al. (U.S. Patent No. 5,661,082) ("Hsu"). This rejection is respectfully traversed and reconsideration is respectfully requested.

Claims 76-78 depend from claim 74 and are allowable over the combination of Okada and Tsai for at least the reasons set forth above with regard to claim 74. Hsu is relied upon as teaching a passivation layer, a via formed in the passivation layer, and possible materials for forming the dielectric layer. Office Action, pg. 3. Applicant respectfully submits, however, that Hsu does not remedy the deficiencies of the Okada and Tsai combination. That is, Hsu also fails to teach or suggest a "copper layer having titanium implanted within and near only an upper surface of said copper layer, said copper layer being primarily copper and having a thickness of about 500 Angstroms to about 20,000 Angstroms . . . wherein said implanted titanium acts to reduce formation of copper oxide on said copper layer."

Accordingly, claims 76-78 are allowable along with claim 74 for at least the reasons set forth above for claim 74. Applicant respectfully requests that the rejection of claims 76-78 be withdrawn and the claims allowed.

Claims 79, 80, 82 and 83 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Edelstein et al. (U.S. Patent No. 6,457,234) ("Edelstein") in view of Harada et al. (U.S. Patent No. 5,565,378) ("Harada") in view of Mahulikar et al. (U.S. Patent No. 5,320,689) ("Mahulikar"). This rejection is respectfully traversed and reconsideration is respectfully requested.

Claim 79 recites an interconnect structure for a semiconductor die including a "conductive bond pad containing a copper layer" where the "copper layer contain[s] a

copper oxide layer thereon” and a “titanium-aluminum-copper-nitrogen layer formed as part of [the] copper layer and from a portion of at least an upper surface of [the] copper layer.” Applicant respectfully submits that the cited combination fails to disclose, teach or suggest the claim 79 invention.

Edelstein relates to a process for fabricating a corrosion-resistant conductive pad on a substrate. Edelstein Abstract. The conductive pad is formed of an alloy derived from a metal layer being annealed with a second metal layer. Edelstein Col. 4, lines 33-60. As stated in the Office Action, Edelstein discloses an AlCu alloy. Office Action, pg. 4.

Harada relates to adding small amounts of one of many possible materials, including copper and titanium, to an aluminum alloy film in order to enhance the resistance to electromigration. Harada Col. 6, lines 54-61.

Mahulikar relates to a composite copper alloy having a copper alloy core and a modified surface layer containing a nitride or carbide film. Mahulikar Abstract. This surface layer acts as a barrier on the surface of an iron or nickel-based alloy, thereby providing improved tribological (i.e., friction and wear) and mechanical properties.

Applicant respectfully submits that Edelstein, Harada and Mahulikar are not properly combinable. There would have been no motivation to combine the references for the purpose of teaching or suggesting a titanium-aluminum-copper-nitrogen layer absent the impermissible use of hindsight using the claims of the present application as a roadmap. The mere fact that references can be combined or modified is not sufficient to establish *prima facie* obviousness, the prior art must also suggest the desirability of the combination, which is not present here. M.P.E.P. § 2143.01 (citing In re Mills, 916 F.2d 680, 16 U.S.P.Q.2d 1430 (Fed. Cir. 1990)).

The Office Action does not provide a motivation to combine these references. The Office Action merely states “it would have been obvious ... to have the titanium ... to enhance the resistance to electromigration” and “it would have been obvious ... to have the nitrogen ... to improve tribological and mechanical properties while maintaining useful electrical conductivity.” Office Action, pgs. 4-5. Applicant respectfully disagrees. Harada relates to the improvement of an aluminum film by adding elements to the aluminum. The present application states that using a copper layer to form the bond pad is itself an improvement over using an aluminum layer, therefore, the references that teach merely improving aluminum cannot disclose the claimed invention. Although Mahulikar relates to an improvement of copper, Mahulikar adds nitrogen to copper resulting in improved properties of an iron or nickel-based alloy, not a copper-based alloy.

Moreover, neither Harada nor Mahulikar provides any motivation to combine their teachings with bonding pad references in order to reduce oxidation of copper. Accordingly, Applicant respectfully submits that one skilled in the art would not have been motivated to combine the references in the manner suggested by the Office Action.

Accordingly, claim 79 is allowable over the cited combination. Claims 80, 82 and 83 depend from claim 79 and are allowable along with claim 79. Applicant respectfully requests that the rejection be withdrawn and the claims allowed.

In view of the above amendment, Applicant believes the pending application is in condition for allowance.

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Respectfully submitted,

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